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REPORT ON  
PROPOSED PULP MILL SITES IN MONTANA  
IN RELATION TO MILL EFFLUENT EFFECTS ON  
QUALITY OF WATER OF THE UPPER MISSOURI  
AND YELLOWSTONE RIVERS

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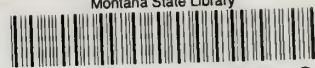
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TECHNICAL SERVICES BRANCH  
DIVISION OF WATER POLLUTION CONTROL  
PUBLIC HEALTH SERVICE, FEDERAL SECURITY AGENCY

IN

COOPERATION WITH THE  
MONTANA BOARD OF HEALTH  
AND THE  
FOREST SERVICE  
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.  
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#### Stream Flow Data

Map No. 1 Areas of Pulpwood Sources

Map No. 2 Canyon Ferry Reservoir Site



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*Headwaters of Missouri River — Three Forks, Montana*

Figure - 1 Pulp Mill Locations suggested include sites near  
Junction of the Jefferson, Madison, and Gallatin  
Rivers, forming the Missouri River.



PROPOSED PULP MILL SITES IN MONTANA  
IN RELATION TO MILL EFFLUENT EFFECTS ON  
QUALITY OF WATERS OF THE UPPER MISSOURI  
AND YELLOWSTONE RIVERS

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FOREWORD

The following report summarizes information obtained in a preliminary study of pulp mill sites that have been suggested for development in the State of Montana East of the Continental Divide, considered from the point of view of possible effect of effluents on water quality in the Upper Missouri River and Yellowstone River Basins. The reconnaissance survey of contemplated sites, made at the request of the State Board of Health, was conducted during the period, August 6-10, 1951. Sites covered were in the vicinity of Billings and Livingston along the Yellowstone River, Three Forks, Winston, and Great Falls, along the Upper Missouri River. The Forest Service, Missoula Office, U. S. Department of Agriculture, the Montana State Chamber of Commerce, as well as the State Board of Health, and other Federal, State and local agencies, are interested in the proposal to build pulp mills in the area, and participated in visits to sites considered, or attended meetings and conferences arranged as a part of the survey. Subsequent to the initial observations made and gathering of information started in Montana, supplemental data and material have been furnished by numerous individuals and agencies.

ACKNOWLEDGMENTS

The assistance of Mr. C. W. Brinck, Mr. H. B. Foote, and Mr. H. W. Taylor of the Division of Environmental Sanitation, Montana State Board of Health in obtaining essential information and data used in this study is gratefully acknowledged.

The cooperation of the Missoula Office, Forest Service, U. S. Department of Agriculture, in furnishing various facts relating to the contemplated pulp mill developments, especially the aid of Mr. I. V. Anderson, is acknowledged with appreciation. Mr. G. H. Chidester of the Forest Products Laboratory has provided valued assistance. The Montana Power Company, through Mr. R. C. Setterstrom furnished hydrologic data and other helpful information. Acknowledgment is also



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made to the Bureau of Reclamation, Fish and Wildlife Service, and Geological Survey, Department of Interior, Federal Power Commission, and the Missouri Drainage Basin Office, Division of Water Pollution Control, Public Health Service, Federal Security Agency, for assistance rendered in obtaining data, for information from their published reports, and for comments and suggestions made covering water storage and irrigation, stream discharges, power projects, existing pollution, and other items relating to developments in the Yellowstone and Upper Missouri River Basins.

#### SUMMARY AND CONCLUSIONS

The findings from this survey are briefly as follows:

1. The development of a wood pulping industry is being considered for the Western portion of the State of Montana. Attention is being given to the possibilities of pollution arising from such a development.
2. Sites for pulp mills given attention herein are confined to the Yellowstone and Upper Missouri River Basins. Those now being considered are situated in the vicinity of Billings, Livingston, Three Forks, Winston, and Great Falls, Montana.
3. The method of wood pulping contemplated for the proposed mills is the sulphate, or kraft, process. Other processes, however, are not excluded, but at present are not being given primary consideration.
4. The introduction of pulp mill wastes into a stream will have some effect on the character or quality of water in the stream. The important consideration is whether these changes will have a detrimental effect on the existing and desirable uses of the stream below the pulp mill and the extent or degree of the detrimental effects, if any, on such water uses.
5. The establishment of a 200 ton kraft pulp mill in the vicinity of Livingston will not result in depletion of dissolved oxygen below limits required for fish or other desirable aquatic life. At this site, it is possible that toxic effects of the mill wastes may appreciably



reduce the desirable fish populations for a limited distance below the mill. The mill effluent may necessitate appropriate treatment for removal of color, taste, and odors from any public drinking water supplies that are obtained in the future from the Yellowstone for a short distance below Livingston. No present water supply will be affected. Effects on the esthetic quality of the stream will be limited to a very short sector of the stream below the mill. There should be no appreciable effect on the suitability of the water for irrigation. It is concluded from presently available information and data that Livingston is a less suitable site for a pulp mill than some of the others considered.

6. The combined effects of the very considerable amount of organic wastes now being discharged in the vicinity of Billings and the wastes from a 200 ton kraft pulp mill will deplete the dissolved oxygen concentration in the stream below that considered necessary for maintenance of a maximum desirable fish population. The effect the mill effluent would have on the appearance of the Yellowstone River and its suitability for irrigation and as a source of drinking water supply for any future developments downstream are similar to those described for Livingston. It is concluded that Billings is a relatively unsuitable site for the location of a pulp mill, principally because of the considerable pollution load already being discharged to the stream in this vicinity.

7. The establishment of a 200 ton kraft pulp mill in the vicinity of Three Forks and discharging wastes below the junction of the three rivers forming the Missouri, should not reduce the dissolved oxygen in the stream below the concentration considered adequate for fish. Considering dilution available and other factors, it is not expected that any toxic effects of the wastes will appreciably reduce the fish population in the stream. Color, taste and odor producing substances in the wastes may render the Missouri River from the mill to the Canyon Ferry Dam somewhat less satisfactory as a source for public drinking water supplies. Such supplies are not presently obtained from the River in this area. There will be no appreciable effect on the suitability of the water for irrigation. Impairment of the esthetic quality of the stream will be limited to the very short sector below the mill waste outlets. It is concluded from the available information and data that it appears feasible to establish a 200 ton kraft pulp mill at Three Forks without creating material pollution of the stream and that further consideration of this site is justified.



8. The effects on the stream of the effluent from a 200 ton kraft pulp mill located near Winston and discharging wastes into the Missouri River, a few miles upstream from the slack water of the Canyon Ferry Reservoir, should not vary materially from those described for the Three Forks site. It is concluded from the available information and data that the vicinity of Winston justifies additional consideration as a pulp mill site. Mills should not be established at both the Winston and Three Forks sites at the same time as the effect of the wastes on the waters will be cumulative to a considerable extent.

9. The establishment of a 200 ton kraft pulp mill near Great Falls should not appreciably reduce the desirable fish populations in the stream. The effluent might possibly increase color, taste, and odors in the Fort Benton water supply to the extent that additional treatment would be necessary. There should be no appreciable effect on the suitability of the river water for irrigation. Limited effects on the esthetic quality of the stream will exist only in a very short sector of the stream below the mill waste outlets. It is concluded from available information and data that Great Falls is a relatively suitable site for a kraft pulp mill and justifies additional consideration.

10. It is recommended that as a part of future planning for any pulp mill projects in Montana there be included complete stream surveys of those portions of the rivers that may be significantly affected by the wastes. The purpose of these surveys would be to determine as accurately as possible existing physical, chemical, biological and other factors that would govern mill production capacity in relation to waste disposal at each specific site.

#### GENERAL INFORMATION

##### Request:

The Montana State Board of Health through the Division of Environmental Sanitation initially made inquiry as to what assistance might be furnished by the Public Health Service in determining water pollution possibilities in connection with the proposed establishment of pulp mills in Montana. It was requested that aid be provided in making surveys of sites, starting with wood pulping developments in prospect East of the Rocky Mountains. The request was confirmed in a letter from Dr. G. D. Carlyle Thompson, Executive Officer of the Montana State Board of Health. Mention was made in the letter of the interest of the Missoula



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Office, Forest Service, U. S. Department of Agriculture, in this matter and the tentative plans being made for an inspection of sites and gathering of information that would be needed in rendering assistance desired by both the Forest Service and the Montana State Board of Health

#### Purpose:

The purpose of this study is to make a preliminary estimate from the existing available data of the extent and effects of pollution which would result from the establishment of sulfate pulp mills at several locations in Montana. It is intended to serve only to indicate the approximate pollutional effects expected at several proposed sites for the purpose of determining whether additional consideration and study of a particular site is justified.

#### FIELD WORK

In compliance with indicated requests for assistance, and in keeping with arrangements outlined by the Division of Environmental Sanitation, Montana State Board of Health, an inspection was made of the several areas being considered as possible sites for future pulp mills in that part of Montana East of the Continental Divide. The field work involved observations along the Yellowstone River from Billings to Livingston, and the Missouri River from the junction of the Jefferson, Madison and Gallatin Rivers shown in Figure 1, near Three Forks to the Morony Dam downstream from Great Falls. The trip, during the week of August 6-10, 1951, included a number of meetings and conferences in developing a background of information in connection with this preliminary survey of stream pollution possibilities of proposed pulp mills at sites along these two rivers.

#### Survey Group:

Those participating in the survey, starting at Billings, were as follows: Mr. H. B. Foote, State Sanitary Engineer, and Mr. H. W. Taylor, Sanitary Engineer, Montana State Board of Health; Mr. I. V. Anderson, Chief, Forest Utilization Service, Missoula Office, Forest Service, U. S. Department of Agriculture; Mr. R. C. Sotterstrom, Industrial Engineer, Montana Power Company; and L. F. Warriek, Chief, Technical Services Branch, Division of Water Pollution Control, and for that portion of the trip from Helena through Great Falls along the Missouri River, Mr. C. W. Brinck, Director, Division of Environmental Sanitation, Montana State Board of Health.



#### Procedure:

The procedure followed in the field work was to inspect the mill sites being considered, frequently in company with interested local citizens, to contact officials and others who could furnish needed data or information, and then to meet with representative local groups under a definite schedule arranged in advance, including luncheon and evening sessions. The object was to promote the maximum interchange of information on all aspects of the pulp mill projects, particularly as they related to the effects of mill effluents on quality of surface waters.

In this connection, inquiry was made into water uses in the area, covering municipal, industrial, agricultural, recreational and other interests involved. The anticipated future developments as well as current construction that might influence consideration of sites were reviewed. Water works officials were contacted when possible and their records reviewed. Data obtained along with that furnished by the State Board of Health provided needed background for studies covered by this report.

The travel by automobile between the various locations suggested for pulp mills made it possible to pause and view flow conditions along the Yellowstone and Upper Missouri Rivers. Rapids, with turbulent flows were observed in many places along the Yellowstone while there were a number of quiet stretches of water behind dams along the Upper Missouri River. This gave helpful information in connection with estimates of stream aeration and oxygen resources available for oxidation of such wastes as would be discharged from pulp mills.

Contacts were made with the operating staff of some power plants along the Missouri River, where records of flows and water temperatures have been kept. Through the courtesy of the Montana Power Company such data as needed was made available to aid with this survey. Similar courtesy was extended by the Bureau of Reclamation through the members of the engineering staff contacted at the place where the Canyon Ferry Dam is currently under construction, shown in Figure 2 of this report. The full details on the surface area and storage capacity at various elevations of the lake that will be created upstream from this dam were obtained.

The survey of pulp mill sites and sections of the two rivers that would receive mill effluents was followed with a general meeting in the State capitol building in Helena, attended by representatives of local, State and Federal agencies and citizen groups interested in the problems involved, including water pollution as one of special importance, in the contemplated development of pulp mills in Montana.



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Figure 2 - Canyon Ferry Dam under construction along the Missouri River near Helena, Montana. The Reservoir created will extend upstream from the dam to the vicinity of pulp mill sites suggested near Winston, Montana.



Attendance at Meetings:

The survey group contacted the following individuals during the week at meetings that were scheduled along the route followed in the field work.

A noon meeting, August 6, was held at Billings with those in attendance being:

Mr. J. M. Halterman, Aquatic Biologist, Billings Office,  
Fish and Wildlife Service, U. S. Dept. of Interior,  
Mr. Herbert Martin, State Manager, Standard Oil Company,  
Mr. P. S. Goan, Proprietor, Dude Rancher Lodge.

A group meeting was held at Livingston on August 7, attended by:

George Kern, Chief accountant, Northern Pacific Railway,  
Kendall F. Stieves, Manager, Livingston Chamber of Commerce,  
Mack Anderson, President, Livingston State Bank,  
Henry Reilly, Office Manager, Montana Power Company.

At Three Forks the survey group met the following individuals, who went along on an inspection of mill sites in that area, and with whom the project was discussed during the evening of August 7:

Mr. Max Makoff, Proprietor of Sacajawea Lodge,  
Mr. C. M. Sorensen, hardware merchant,  
Mr. George McPhail, oil distributor,  
Mr. Paul S. Stephenson, merchant,  
Dr. E. E. Bertagnolli, local physician.

In Great Falls on August 8, the following individuals attended a noon meeting to discuss the pulp mill projects in relation to water pollution:

Mr. Lou Siniff, Manager, Corral Sporting Goods Store and a member of the Montana Wildlife Association.  
Mr. Lee Metcalf, Great Northern Railway Company, also a representative of the Wildlife group and the Isaac Walton Chapter,  
Mr. Lloyd Kenyon, Manager, Great Falls National Bank,  
Mr. H. R. Welter, President of the local Chamber of Commerce, and in the insurance business,  
Mr. R. F. Kitchingman, Manager of the local Chamber of Commerce.



The meeting, which was held in the Senate Chamber of the State Capitol Building, Helena, Montana, on August 9, was attended by the following:

- Mr. L. T. Anderson, Chief, Forest Utilization Service, U. S.
- Mr. E. S. Beebe, Missoula, Montana,
- Mr. W. A. Bunker, Director, Division of Environmental Sanitation, State Board of Health, Helena, Montana,
- Mr. E. H. J. Canady, Acting Manager, Montana Chamber of Commerce, Helena, Montana,
- Mr. Fred C. Carr, State Engineer, Helena, Montana,
- Mr. Henry W. Carr, Chief, Division of Mechanics, N.M. Experiment Station, U. S. Forest Service, Missoula, Montana,
- Mr. A. W. Clarkson, Asst. Director, Sanitary Engineering, State Board of Health, Helena, Montana,
- Mr. E. L. Draper, Bureau of Reclamation, Great Falls, Montana,
- Mr. James E. Ewell, State Board of Health, Helena, Montana,
- Mr. E. L. Forde, Director, Sanitary Engineering, State Board of Health, Helena, Montana,
- Mr. E. D. Hanson, Regional Forester, U. S. Forest Service, Missoula, Montana,
- Mr. E. A. Helm, Bureau of Reclamation, Great Falls, Montana,
- Mr. Paul Ingebo, N.M. Experiment Station, U. S. Forest Service, Missoula, Montana,
- Mr. J. G. Lightfoot, Corps of Engineers, Fort Peck Dist., Fort Peck, Montana,
- Mr. H. B. Morrison, State Board of Health, Helena, Montana,
- Mr. R. H. Plator, Sanitary Engineer, Morrisroe-Maierle, Inc., Helena, Montana, (Chairman, Montana Sewage and Industrial Wastes Assoc.),
- Mr. Ashley Roberts, Manager, Helena Chamber of Commerce, Helena, Montana,
- Mr. J. H. Safford, Livestock, Sanitary Board, Helena, Montana,
- Mr. John B. Schenck, U. S. Fish and Wildlife Service, Helena, Montana,
- Mr. D. C. Scherstrom, Industrial Development Division, Montana Chamber of Commerce, Butte, Montana,
- Mr. Frank Stennitz, U. S. Geological Survey, Helena, Montana,
- Mr. H. W. Taylor, State Board of Health, Helena, Montana,
- Mr. H. K. Thompson, Director, Public Relations Division, Montana Fish and Game Commission, Helena, Montana,
- Mr. D. J. Ward, Bureau of Reclamation, Regional Office, Billings, Montana,
- Mr. H. P. Wilkins, State Veterinarian, Helena, Montana,
- Mr. L. F. Warrick, Division of Water Pollution Control, U. S. Public Health Service, Washington, D. C.



In addition to the above individuals contacted at meetings, there were a number of persons talked with along the route of the survey who furnished data and information of assistance, and who provided background concerning local views on proposed developments.

#### Areas Involved:

The areas involved as the source of pulpwood for potential mills, along with the locations of the sites considered in this preliminary survey, are shown in Map No. 1, appended. The Billings site is the only additional site for a mill considered in this report that is not shown with a colored portion of the map showing the potential source of pulpwood for the mill. In the event of construction of a mill in the future at this location, further study will undoubtedly need to be given to the pulpwood supply situation. Also there are present water pollution problems in the Yellowstone Basin (1), and which will be discussed later.

Pulpwood producing areas shown are only those East of the Continental Divide in Montana. There are similar developments under consideration in the Western portion of the State, such projects to be given attention from the pollution point of view in future studies.

The locations viewed as potential sites for pulp mills are designated by areas circled on Map No. 1. The routes followed between this site may be traced on this map. The survey group proceeded from Billings to Livingston along the Yellowstone River on U. S. Route #10, and from there West on the same highway through Bozeman pass to Three Forks. On leaving Three Forks U. S. Route #10N was followed North through Winston to Helena. The conditions along the Upper Missouri River were viewed through a trip to the Canyon Ferry Dam and area to be occupied by the new reservoir, Figure 2 and 3, and by following U. S. Route #51 to Great Falls. Access to the Holter Dam and lake was from this last mentioned highway. It will be evident from the map that most of the sections of the rivers involved could be observed from the routes followed.

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(1) Yellowstone River Drainage Basin: A cooperative State-Federal Report on Water Pollution, January, 1952, Water Pollution Series No. 23 Montana Board of Health, N. Dakota Dept. of Health, Wyoming Dept. of Public Health, and Missouri Drainage Basin Office, Public Health Service Federal Security Agency.



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Figure 3 - Views of Dam of the Montana Power Company and existing Lake Sewell upstream from the Canyon Ferry Project. Most of the area in the foreground will be flooded by the new reservoir, providing water storage capacity of over two million acre feet in this part of the Upper Missouri River Basin.



Limited storage of water is provided by present reservoirs created by hydroelectric developments along the Upper Missouri River, but completion of the Canyon Ferry project will provide in excess of two million acre feet of storage affecting minimum flows to be expected below the dam site near Helena.

Municipal, agricultural, industrial, recreational and other developments were observed in the area involved in this survey. General conditions existing are described under the following sub-headings.

Yellowstone River Basin: The previously mentioned report of Water Pollution in the Yellowstone Basin (1), summarized existing conditions, stated, in part, as follows:

The drainage area of the Yellowstone is rich in natural resources. Its soils are fertile and only the addition of water is needed to produce abundant crops of wheat, beans, legumes, and sugar beets. Vast oil fields underlie the area producing large amounts of crude oil for the petroleum industry. Quantities of coal, gypsum, bentonite, sulfur, phosphate, gold, chromite, copper, tungsten, silver, iron, zinc, lead, and molybdenum are mined annually. The Yellowstone's waters have great potentiality for hydroelectric power.

"The population of the Basin is relatively sparse and communities are small and widely separated. Billings, Montana, is the largest city with a population of 31,724 in 1930. Most of the cities are located on or near the watercourses and use the streams extensively for water supply and sewage disposal. Sport fishing is a thriving and valuable use of water in the headwaters of the Yellowstone and its several tributaries. The swift currents and cold temperature of the water are not conducive to bathing.

"Industrial wastes containing oil, phenolic compounds, cyanide, rock flour, and other substances have taken a heavy toll of fishery values. Toxic materials have caused more damage to fish life than have organic wastes. Significant depletion of oxygen has never been reported in any of the streams in the Basin. There is evidence, however, to indicate that some public water supplies have been adversely affected by pollution. The use of polluted waters for the irrigation of food crops is a matter of considerable concern to health authorities. . . .

". . . The effect of the regulation of streams on sewage and industrial waste disposal needs has not yet been ascertained. Additional information concerning reservoir releases will be needed before an



evaluation can be made. The removal of settleable materials from both domestic sewage and industrial waste is recommended by pollution control agencies of the Basin as a minimum requirement for controlling pollution. . . ."

The report provides considerable additional information of value used in the present study, but reference is made to this document <sup>(1)</sup> for such details.

Upper Missouri River Basin: There has been issued recently a similar report on pollution for the Upper Missouri River Drainage Basin <sup>(2)</sup>. The essential information for this area relating to this survey is described, in part, as follows:

"The natural resources are many and great. The mountains are covered with extensive forests, and considerable quantities of gold, silver, lead, zinc, coal, and phosphate are mined from them each year. Oil and gas are produced from widely scattered fields. Snow-fed streams flowing downward from the mountains are used to generate large quantities of electrical power and to provide water for numerous irrigation projects. Soils of high fertility are found in numerous places, but in most instances need water in order to produce abundant yields of wheat, alfalfa, sugar beets and similar crops. The natural beauty of the mountains and waterways is becoming an increasingly important tourist attraction, as revenue in Montana from the tourist trade now closely rivals that from agriculture or industry.

"Much of the Basin is semiarid to arid, with most of the precipitation occurring as snowfall. Streams originating in and flowing through the mountainous sections generally have stable flows while those originating in and flowing through the high plains usually have smaller and more erratic flows. Water conservation is necessary in much of the area to provide for domestic needs, irrigation, power production, livestock watering, and recreation, including fishing, hunting, swimming, and boating. The more stable headwater streams, together with mountain lakes, provide outstanding trout fishing.

"The potential of the water resources is being developed by local, State, and national interests. Development is greatly enhanced by the Missouri River Basin water and land conservation and development program which proposes to construct 19 new reservoirs in the region.

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(2) Upper Missouri River Basin: A cooperative State-Federal Report on Water Pollution, May, 1952, Water Pollution Series No. 25, Montana Board of Health, and the Missouri Drainage Basin Office, Public Health Service, Federal Security Agency.



Some of the reservoirs have not as yet been authorized. The tremendous Fort Peck Reservoir has been in service since 1938. Its prime purpose has been to supply water for navigation and to ameliorate flood flows in the Lower Missouri River, the middle and Lower Mississippi River, and incidentally to produce power. Most of the new reservoirs will be multiple-purpose projects.

"The Upper Basin is relatively sparsely populated, averaging less than 3.6 people per square mile. Its major cities are Great Falls, Helena, and Bozeman, Montana, with 1960 populations of about 39,000, 17,500, and 11,280 people respectively. Principal industries include the purification of copper, zinc, lead, silver and gold; refining of petroleum; flour milling; and beet sugar production. The grazing of livestock on the vast pasture lands was one of the earliest occupations and remains an important agricultural pursuit."

For details concerning existing conditions in the Upper Missouri River Basin, reference should be made to the indicated report. Views showing areas near proposed mill sites, the character of various sections of the stream, hydroelectric installations, reservoir areas, and other developments are shown in Figures 1 to 6.

#### PULP MILL SITES

The pulp mill sites that have been proposed, see Map #1, take into account both the pulpwood conveniently available from renewable timber resources in the mountain areas, shown in color on the map, and the water resources available for pulp mill operations and dilution of effluents. These sites are considered from these points of view under the following sub-headings:

##### Livingston Mill Site:

The site at Livingston (Elev. 4,488, U.S.C.S.) is a convenient milling point for much timber on the Gallatin National Forest and some on the Custer National Forest. It is estimated that the allowable annual cut of pulpwood tributary to this point is 127,000 cords broken down as follows by species.

	Cords
Douglas fir	25,073
Alpine fir	4,985
Spruce	11,426
Lodgepole pine	81,439
White bark & limber pine	2,552
Aspen	619
	<u>127,064</u>



As regards stream flow records, kept since October 1937, the minimum flow of the Yellowstone River at Livingston was 590 cubic feet per second on January 22, 1940.

One of the important considerations in establishing a pulp industry near Livingston is the effects any plant located here would have on the recreational use of the stream which is famous for its fishing.

#### Billings Mill Site:

As before mentioned, no pulpwood resource area is shown in color on Map #1 for a proposed mill site at Billings (Elev. 3,127 U.S.G.S.)

Some of the timber tributary to Livingston might as an alternative be pulped at Billings. The annual allowable cut of pulpwood which could be supported by this timber is approximately 69,000 cords.

	<u>Cords</u>
Douglas fir	11,810
Alpine fir	2,778
Spruce	6,800
Lodgepole pine	46,229
White bark & limber pine	1,064
Aspen	272
	<u>68,953</u>

While stream flows in the Yellowstone River at Billings would be higher than at Livingston, consideration of Billings as a pulpmill site must take into account the already existing pollution at this point.

#### Three Forks Mill Site:

The Three Forks mill site (Elev. 4,058 U.S.G.S) would be near the confluence of the Jefferson, Madison and Gallatin Rivers, forming the Missouri. There would be more timber tributary to a pulp mill at this site than to any other point in Eastern Montana with adequate water flow. The allowable cut of pulpwood tributary to Three Forks is estimated to be 442,000 cords per year.



	<u>Cords</u>
Douglas fir	52,727
Alpine fir	23,237
Spruce	32,787
Lodgepole pine	318,988
White bark & limber pine	5,077
Aspen	3,215
	<u>442,031</u>

The allowable cut would come from the Beaverhead, Gallatin, Dearlodge, Helena, and Lewis & Clark National Forests.

The minimum recorded stream flow on the Missouri River near Three Forks since 1932 was 280 cubic feet per second on March 3, 1933.

Because there is such a large allowable cut available for pulping at Three Forks, the question of adequacy of water flow is probably more acute here than at any other one of the milling points considered if a mill of large enough capacity to handle available pulpwood were built at this site.

#### Winston Mill Site:

The Winston mill site (Elev. 4,350 U.S.G.S), located near Helena, might involve a river location or border the reservoir being created by construction of the Canyon Ferry Dam.

Approximately 90,000 cords of pulpwood per year are tributary to the Helena area.

	<u>Cords</u>
Douglas fir	24,815
Alpine fir	3,807
Spruce	5,976
Lodgepole pine	54,500
White bark & limber pine	1,182
Aspen	348
	<u>90,608</u>

One advantage a mill in this locality would have from the raw material supply point of view is that the timber is close by.

Stream flow records at Teston, above Winston, since 1932 indicate a



minimum flow of 280 cubic feet per second on March 3, 1938. With the completion of the Canyon Ferry Dam, any pulpmill located near Winston would be on or near slack water. This raises the question as to whether the practice of discharge of pulpmill effluent into a reservoir is to be preferred to discharge to a stream.

#### Great Falls Mill Site:

The Great Falls mill site (Elev. 3,357 U.S.G.S.), would be in a stream sector now extensively developed for hydroelectric power production, see Figures 4 to 6, and in an area which has made substantial industrial progress. Pulpwood resources at this site would be further from the pulp mill than the upstream locations along the Missouri River.

Approximately 80,000 cords of pulpwood per year are tributary to the Great Falls area.

	<u>Cords</u>
Douglas fir	9,613
Alpine fir	5,839
Spruce	10,086
Lodgepole pine	53,687
White bark & limber pine	1,179
Aspen	568
	<hr/>
	80,972

The stream flow records at Fort Benton, below Great Falls, indicate the minimum flow of the Missouri at that point since 1932 was 627 cubic feet per second on July 5, 1936.

A factor taken into account in these studies in considering Great Falls as a pulpmill site is the existing pollution from industrial waste and sewage.

A further site suggested for construction of a pulp mill was along Wolf Creek, but this was eliminated from consideration in this survey.

#### PULP PRODUCTION

The pulp production possible at each of the foregoing mill sites may be estimated from the cords of pulpwood available, but the matter of water pollution control among other important factors to be considered will



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Figure 4 - Rainbow Dam about 10 miles downstream from Great Falls, Montana, - one of the locations being considered for a pulp mill. During low water periods most of the river flow is diverted above the falls, shown in the foreground, for hydroelectric power production



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Figure 5 - Power plant below the Rainbow Dam, showing canyon restricting the reservoir areas behind the several dams along this section of the Missouri River.



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Developments in Montana



Figure 6 - Below the Morony Dam and Power Plant, there are no flow-ages downstream until the Missouri River reaches the Fort Peck Reservoir. The stream has a fairly rapid flow from this point through Fort Benton, Montana.



Report on Proposed Pulp Mill  
Developments in Montana



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influence final decisions. The proposals to develop such industry in Montana coincides with the growing needs for pulp, which are reflected in the authorization of the Defense Production Administration under date of March 20, 1952. This provides setting forth pulp, paper and paper-board goals for an expansion of 1,034,000 tons annually in unbleached sulphate wood pulp production, to bring the capacity up to 7,212,000 tons per year by 1956.

For the purpose of a comparative study of the mill sites, it was agreed to select a daily production capacity of 200 tons of pulp. The view expressed was that developments in the area under consideration would probably be confined to production of kraft pulp. Other methods of pulping were of interest, however, and it is possible that present views on the kind of pulp production will change. Interest was expressed in other wood pulping procedures, and ways and means for keeping pollutional wastes at a minimum.

In this report the effluent to be expected from a modern 200 ton sulphate, or kraft, pulp mill, with proper operation, as evaluated in studies elsewhere in recent years, was used as the basis of comparison of the suitability of sites suggested for pulp mills in Montana.

To follow-up requests made during the survey and to aid in an understanding of conclusions reached, the process used in a modern kraft mill is described under the following heading.

Before proceeding with this description, however, the information furnished by the Northern Rocky Mountain Forest and Range Experiment Station, Missoula, indicates that there has been an increasing amount of pulpwood marketed in recent years. This pulpwood has been sold to mills in the middle-west. The total amount of pulpwood from the allowable cut in Montana, particularly from the area involved in this survey in South Central Montana, would amply take care of the needs for several pulp mills.

From the conservation point of view, the cut of pulpwood would include dead timber, most of which is lodge pole pine. It is understood this is quite suitable for pulping by the kraft process, being only slightly inferior to green lodge pole pine East of the Continental Divide. It is stated that there is enough of the dead timber available to keep several mills running a long time "without cutting a stick of green timber".



## SULPHATE (KRAFT) PROCESS

### Description:

The sulphate process for making pulp and paper from wood is essentially a procedure for separating cellulose fibers from non-cellulosic substances in the wood. The process gets its name from one of the principal raw materials, sodium sulphate, referred to as salt cake. The term "kraft" is also applied to this process, derived from Swedish meaning strong. A more exact name, chemically speaking, would be the "Sulphide Process", since the sodium sulphate or salt cake must be reduced before use to sodium sulphide. While sulphate and kraft have been used synonymously, kraft has come to mean the high strength product now being manufactured at many mills, particularly in the South.

Initially, use of kraft pulp was confined mostly to coarse papers and board products. Uses for the pulp have been greatly extended. At present even dissolving pulp, containing over 95% alpha cellulose, is produced by the kraft process followed by bleaching treatment for the pulp. Modifications of the kraft process have made it possible to pulp hardwoods as well as pine and other coniferous woods. These developments have contributed to a remarkable growth of the kraft pulping industry in recent years.

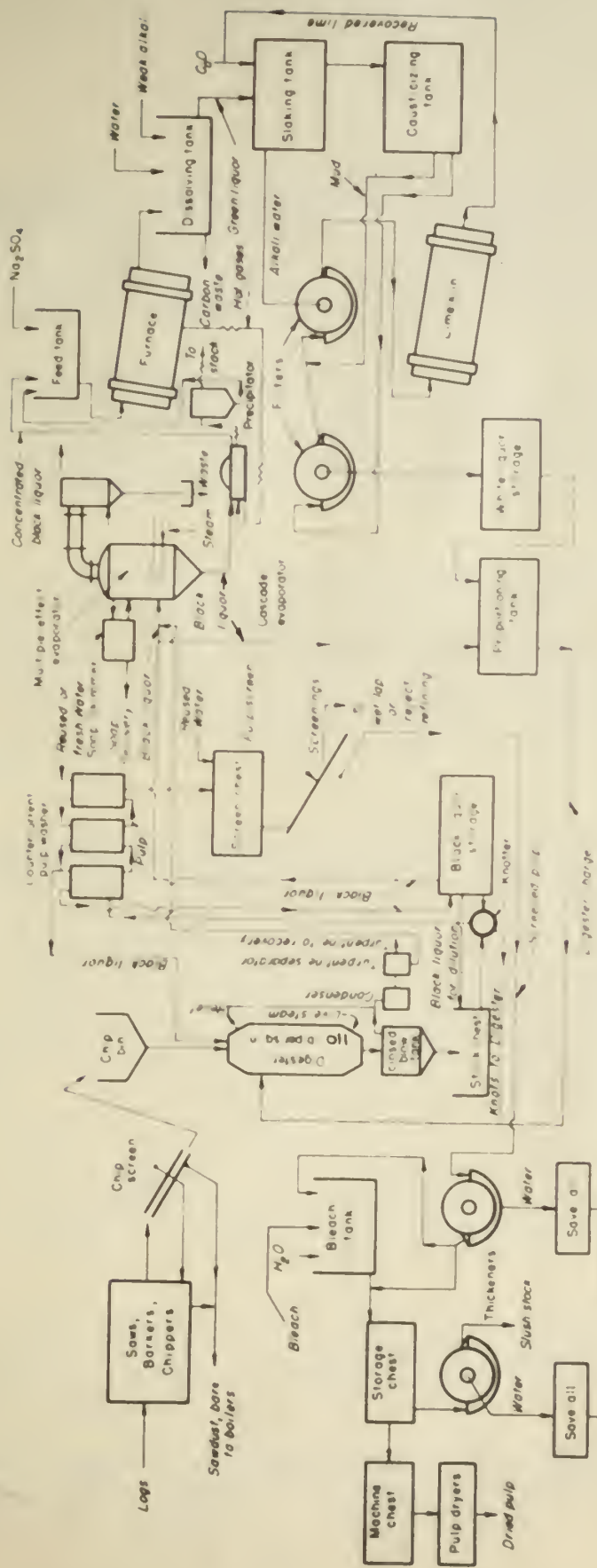
Continuous improvements in equipment and procedure have followed the first use of the process. Chemical requirements for kraft pulping have greatly exceeded most other processes, and its application has always depended on recovery of chemicals and heat value of the lignins and other substances cooked from the wood. Advances during the past ten to fifteen years have brought recovery and utilization facilities available to a high degree of efficiency.

In a modern kraft pulp mill, most of the chemicals are recovered and processed for use again. Recovery values of 95% can be attained. Even dust formed while processing dry materials, and previously lost, is reclaimed by electrostatic methods. Fuel requirements have been reduced by better heat recovery. New equipment keeps pulp losses at a minimum. These developments to reduce waste, together with recovery of by-products, have resulted in more and better pulp with less use of materials.

The attached flow diagram for a kraft pulp mill, Figure 7 will be of assistance in connection with the following description of the kraft wood pulping process.



# FLOW DIAGRAM FOR KRAFT PULP MILL



Essential to minimize waste



Wood Preparation: Pulpwood logs, sawed to suitable length, are conveyed mechanically to revolving barking drums where they are tumbled, rubbing against the sides of the drums and each other until the bark is removed. The bark falls through slots in the drums and is transported by conveyors to the boiler room, where it is burned to supply a part of the mill fuel requirements. The bark has no value in paper making.

Hydraulic barking of pulpwood has been employed in some mills, including some in the Northwest. The bark is removed from the logs by a jet of water operated under high pressure. The velocity of the water hitting the logs effectively strips away the bark and cleans the pulpwood. This requires large volumes of water and may occasion a disposal problem.

Logs with the bark removed are either sent to storage or to chippers. These chippers are heavy rotating discs equipped with steel knives that cut the logs into square chips usually ranging from  $1/2$ " to 1" in size. These must be screened as chips over 1" may not be thoroughly cooked in the time they are in the digesters, and chips under  $1/4$ " would be overcooked, resulting in a loss of wood. Slivers are removed. Rejects are sent to the boiler house for fuel. The chips are stored in round hopper bottomed tanks, called chip bins.

Digestion (Cooking) Process: From the chip bins, the chips are discharged into digesters, large cylindrical steel retorts in which the chips are acted on with suitable chemicals at elevated temperature to effect a separation of cellulose fibers. A digester is charged from the top with a given amount of wood chips, and the cooking liquor is added. The cooking liquor, called "white liquor", is composed of about  $2/3$  sodium hydroxide and  $1/3$  sodium sulphide in solution. Prior to adding any liquor to the digester, the white liquor is analyzed to determine the exact amount of hydroxide and sulphide, called "active alkali". The volume in gallons necessary to give a definite weight in pounds of active chemical is then carefully measured out in proportioning tanks. This volume of white liquor is supplemented with so-called "black liquor"; the liquor once used for cooking which has practically no active ingredients left but is utilized simply for additional liquid volume in filling the digester. Following these charging operations, requiring about twenty minutes, the cover of the digester is bolted tight and steam applied to start the cooking.

The total cooking time is about  $2\ 3/4$  hours, with about  $1\ 3/4$  to 2 hours being required to raise the temperature and pressure to the correct amounts: for example,  $343^{\circ}\text{F}$ . and 110 lbs., respectively. The cooking is continued at full temperature for  $3/4$  to 1 hour.

During this cook, the chemical reaction is essentially hydrolysis of lignin and carbohydrates, with the formation of compounds soluble in water



or excess alkali. Sodium hydroxide is the solvent that acts on the wood chips. The sodium sulphide present does not act directly on the wood, but by decomposing it breaks down to liberate sodium hydroxide as the concentration of sodium hydroxide is reduced by use. Thus the sodium sulphide serves as a reserve supply of sodium hydroxide, making unnecessary a high enough concentration of the sodium hydroxide at any time during the cook to decrease the yield and weaken the pulp. This reaction of sodium sulphide explains the greater yield and stronger pulp produced by the kraft process as compared with the "Soda Process", which also uses sodium hydroxide as the chief solvent. The fats and resins in the wood are saponified, rendered soluble, and later separated and recovered. This recovery is important in reducing pollution, as will be discussed later. Cellulose fiber left free and in suspension, is the pulp.

Another step in the process of interest from the waste control point of view is turpentine recovery. In the steaming of the wood chips, the digester is vented to a condenser. The condensate is passed through a turpentine separator, and the reclaimed turpentine is drawn off to storage.

At the end of the cook, the digester is "blown", the term used for quick emptying of the pulp into a container called a "blow tank." The pressure is brought down to atmospheric, reducing the temperature to about 220°F. and stopping the digestion. The drop in temperature and pressure causes a large amount of low pressure steam to be formed. This steam can be condensed with a jet condenser to water having a temperature of 195° to 200°F., and used for washing pulp.

Pulp Washing: The contents of the blow tank resulting from the emptying of the digester are too thick to pump. It is necessary to dilute the pulp with black liquor from storage to about 4% fiber. The black liquor used is removed from the pulp in washing operations to be described. Automatic equipment is available to control dilution.

Knots may be removed either before or after pulp washing operations, and the knots and big chips that are not cooked are returned to the digester. From the knotter the pulp, referred to at this stage as "brown stock", diluted to about 1 1/2% fiber, is sent to the washers.

In modern mills, the earlier "diffuser" washing facilities have given way to more efficient counter current pulp washers utilizing three or four rotary vacuum filters. Each of these filters has a revolving drum, or cylinder, covered with a stainless steel wire cloth with about 40 meshes to the inch. The lower portion of the filter is under a vacuum and draws the liquor through the wire cloth leaving the pulp on the wire surface, the pulp being washed by showers as the drum slowly turns.



Pulp is washed on the first filter with filtrate from the second stage vacuum filter. The pulp leaving the first stage contains 11% to 15% fiber, which is diluted to about 1% by filtrate from the second stage, passed on to the second filter unit where it is washed with filtrate from the third stage, and again thickened to around 10% to 12% fiber. The process is repeated in the third and fourth stages, except that the final wash is with hot water, reused water generally employed in keeping water requirements and losses at a minimum.

From the last rotary filter in this counter current washing system, the clean stock is discharged to storage. While it is important that the stock be clean, it is also essential that the least possible amount of water be used since it must be evaporated in the chemical recovery cycle to be described.

The washed pulp is delivered at a "consistency" of about 4% fiber to the receiving operation, passing through a weight regulator and from there diluted with water to 1 1/4% consistency going to the screen units.

Pulp Screening: The pulp may be conveyed to ordinary flat screens, or discharged through a mixing pump to a flume flowing to centrifugal screens. The latter type of screen is equipped with fine screen plates against which the pulp flow is thrown by centrifugal force. The last of the uncooked chips and knots are removed. The tailings from the screens are removed and may be reclaimed either as wet lap stock on wet machines, or may be sent to a device which mechanically breaks the rejects up into fiber in the presence of hot liquor. The fiber and liquor are discharged to the blow tank, the process being called "reject refining."

The screened pulp is passed over a thickener to take out water and produce "deckered" stock of about 6% fiber. The pulp is delivered to storage, ready now to be pumped, diluted to suitable consistency with "whitewater", or reused water, to the pulp bleaching system, or direct to the machine chest and equipment for converting the pulp into the final product.

Chemical Recovery System: As previously pointed out, the chemicals used in the kraft process are recovered in large part and not permitted to go to waste. The flow from the counter current pulp washers containing most of the spent chemicals, called black liquor because of its dark color, is conveyed to a black liquor storage tank. The black liquor goes through a chemical recovery system, which may be briefly described as follows:



Essentially the procedure involves removal of water from the black liquor by evaporation, separation of organic and inorganic materials by burning out the organic substances, addition of salt cake make up at the furnace with its chemical reduction under temperatures maintained in the furnace and causticization of the soda with lime and with later recovery of the lime by burning to remove carbon dioxide in a lime kiln. Reference to the flow diagram, Figure 7, will be helpful in following the main steps in the chemical recovery cycle.

The weak black liquor is concentrated to a viscous solution of about 50% solids by steam heated, multiple effect evaporators, and subsequently evaporated further by being exposed to hot flue gases from the recovery furnace. This exposure to hot gases takes place in a cascade evaporator. In modern practice as many as six or seven evaporator units may be employed in multiple effect evaporation to make the least amount of steam remove the maximum amount of water from the black liquor.

A weighed amount of salt cake is added to the concentrated black liquor before being sprayed into the furnace. There is enough organic matter in the solids to burn and evaporate water left in the black liquor, with enough heat to spare for generation of steam in a boiler located over the furnace. In the furnace a reducing atmosphere is maintained to convert the sodium sulphate to sodium sulphide by the reaction  $\text{Na}_2\text{SO}_4 \xrightarrow[\text{Heat}]{2\text{C}} \text{Na}_2\text{S} + 2\text{CO}_2$ . This reaction requires heat in addition to that required for evaporation of the remaining water in the black liquor, but there is still sufficient for production of steam needed in the process.

A molten smelt is discharged from the furnace which looks like molten slag, or iron issuing from an iron blast furnace. This smelt is essentially sodium carbonate and sodium sulphide. It is dissolved in weak wash liquor from the causticizing operations, or reused water from other sources, until a total alkali concentration in the dissolving tank of about 1 pound of sodium oxide ( $\text{Na}_2\text{O}$ ) per gallon is produced. The resulting solution is known as "green liquor". When the proper concentration is reached, it is ready for use in the causticizing step in the chemical recovery cycle.

Hot flue gases after passage from the furnace through the cascade evaporator still contain considerable fine dust. In earlier days the practice was to discharge this to the atmosphere. Modern mills usually are provided with electric precipitators designed to remove more than 90% of the fine dust, or smoke particles, which are essentially very fine particles of sodium sulphate. These are given an electrical charge and in passing through an electrical grid, the particles are attracted to rods



having an opposite charge. The smoke particles deposited on the rods are removed and mechanically returned to the chemical recovery system.

Causticizing: Green liquor is received while hot from the recovery system and clarified. Dregs removed are thickened, washed, and discarded. Clarified green liquor is discharged to storage, then heated to near boiling in connection with the next operation, which is treatment with lime for causticizing. The green liquor and lime are proportioned into the slaking tank, with conversion of sodium carbonate to sodium hydroxide of about 80%, the reaction being  $\text{Na}_2\text{CO}_3 + \text{CaO} + \text{H}_2\text{O} = 2\text{NaOH} + \text{CaCO}_3$ . Commercial lime is used, containing some rock, so it is necessary to remove the rock and grit by a classifying unit. The material removed is washed and discarded. The causticized green liquor requires time for completion of the above reaction, usually carried out with mechanical agitation or stirring. The time of contact under agitation is important, since the longer the time the higher the conversion of carbonate to caustic can be carried and with less excess of lime. The usual time is 1 1/2 to 2 hours. The fully causticized green liquor still containing the lime sludge is called "white liquor".

The white liquor must be freed of the lime sludge. This can be accomplished with a sludge filter, or by suitable clarifiers. The clarified liquor is discharged to white liquor storage to be used again in the pulping process previously described.

The lime sludge is then diluted with filtrate from the sludge filters, and sent to a sludge washing system. The counter current principle is again used. The clean, washed and thickened sludge, 56% to 58% solids, is conveyed to a lime kiln for calcining.

Lime Recovery: This step in the operation is essentially to convert the lime to a suitable condition for reuse. Sludge from the filters is conveyed to a gas or oil fired lime kiln, and it is subjected to increasing temperatures as it passes toward the firing end. The sludge is completely dried, and then gradually heated until the temperature exceeds 1610°F. when it is calcined to quick lime, following the reaction  $\text{CaCO}_3 + \text{Heat} = \text{CaO} + \text{CO}_2$ . This reaction proceeds faster as the temperature approaches 2000°F. The quick lime is then ready for further use in treating green liquor in the slaking tank.

Dust that might cause atmospheric pollution if discharged with the lime kiln flue gas can be controlled by passing through a water scrubber, trapped, and returned to the kiln.



## KRAFT PULPING WASTES

The waste effluents from the kraft pulping process described carry materials the amounts of which depend upon equipment provided to reduce losses and efficiency of individual plant operation. About half of the pulp wood used is dissolved in the cooking liquor leaving a residue of cellulose fibers as pulp. Spent liquors contain the lignin, hemicellulose and sugars from the wood along with chemicals and a small amount of fiber lost in the washing and dewatering operations. Most of the dissolved materials are concentrated and burned for their fuel value in the chemical recovery system.

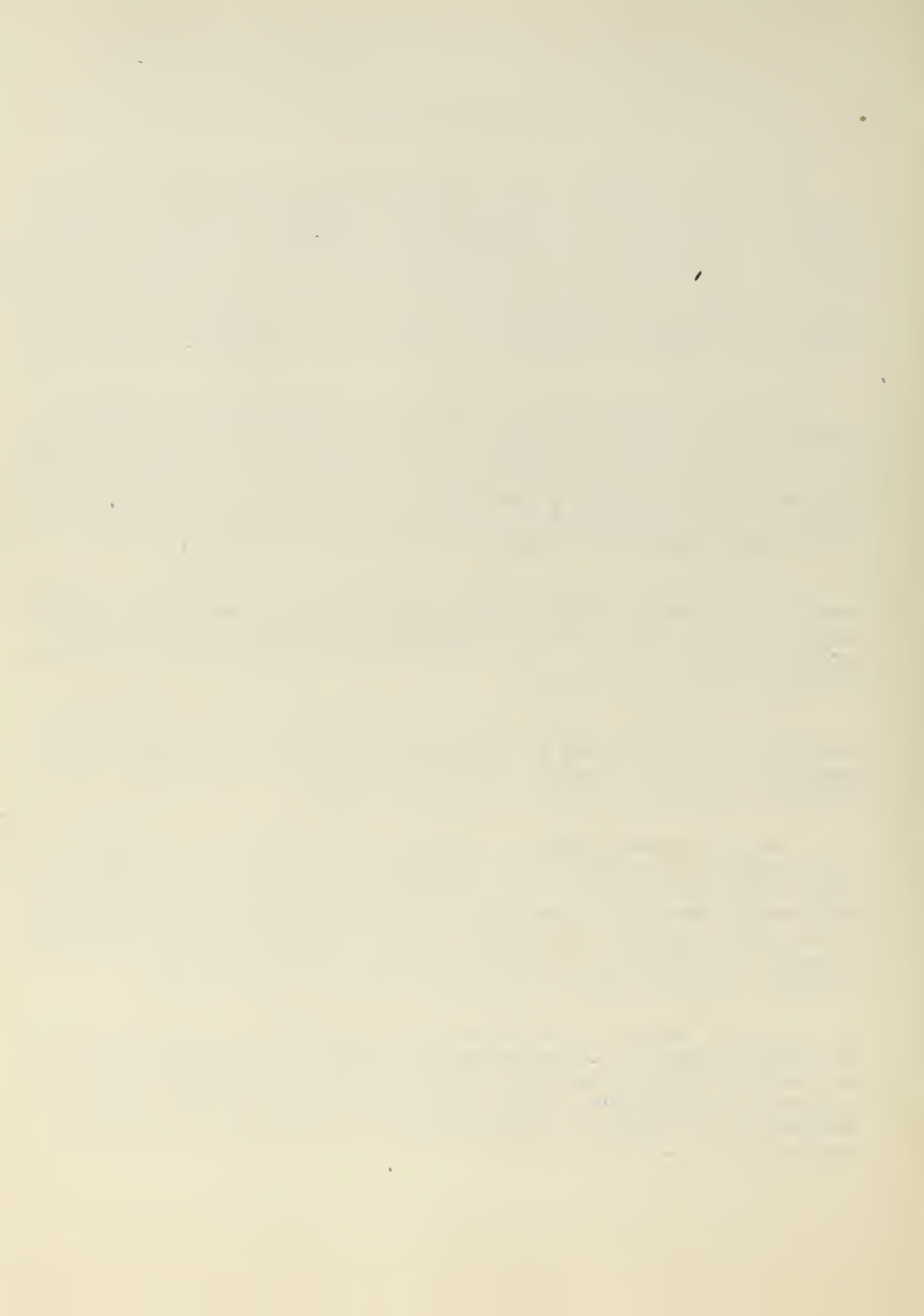
In modern kraft mills the procedure in handling wastes consists essentially of burning the bark from the pulp wood, burning or recocking the knots, reprocessing or marketing the rejects and screenings, recovering and selling of turpentine and tall oil, reclaiming of lime sludge from the causticizing operation, recovering the fiber for including in the product, along with the reclaiming of the heat values of dissolved substances in the spent cooking liquor and chemicals utilized in the process.

Chemical recovery has reached a high state of efficiency. Operating results at modern mills have shown 95% recovery, one new mill reporting only 70 pounds of salt cake as the required make up for chemicals lost per ton of pulp produced. This mill is fully equipped to keep both stack and sewer losses at a minimum.

Wastes that remain for disposal include lime slaker grits and dregs from the causticizing step in preparation of the cooking liquor. These insoluble inorganic materials are usually disposed of in lagoons, or are dewatered and disposed of as fill near the mill.

The process waste water or effluent that needs to be disposed of from a kraft mill will usually range between 20,000 and 40,000 gallons per ton. This is made up of those waters not reused in the process, and which contain varying amounts of spent chemicals and wood substances not reclaimed in the steps previously described. Such an effluent is either discharged directly from the mill, or is lagooned for controlled release, or is given suitable treatment prior to entering a stream or other waters.

The major effect of the effluent on the receiving waters is removal of dissolved oxygen. If the oxygen is depleted sufficiently fish will suffocate, or migrate and other objectionable conditions will occur. It is necessary, therefore, to keep oxygen requirements of the wastes as discharged to a stream at a sufficiently low value to prevent serious oxygen depletion.



The oxygen demand of a waste may be expressed in pounds required per unit of product, such as pounds of B.O.D. per ton of kraft pulp. This may be compared with the oxygen requirement of domestic sewage by dividing the pounds of B.O.D. of the wastes per ton by the amount of oxygen required per person to oxidize sewage, giving the 'population equivalent' of the wastes. The population equivalent on the basis for each ton of kraft pulp produced would range from 250 to 400, the latter figure being used in the studies to be described. Since a modern mill should be able to keep the population equivalent below 300, a factor of safety has been introduced to take care of any unusual operating condition.

Other considerations involve reduction of constituents responsible for imparting color, taste and odor to waters used for public water supply. It is essential to keep certain substances such as mercaptans, resin acids, and sulfides in the condensates, turpentine decanter and floor washings below the amounts that are toxic to fish and aquatic life needed as fish food. A modern development to reduce toxic materials has been to use stripping towers for the condensates, utilizing stack gases from the power plant.

The principal waste from the pulping process is the overflow from the decker seal pit, which contains those chemicals and wood constituents that were not removed in the pulp washing. It varies in strength from 200 to 500 ppm of B.O.D. The greatest step in improving this part of the process has been the development of counter current vacuum washing systems that have practically removed such washings from the mill effluent. Chemical recovery was increased and the B.O.D. of the effluent was reduced at least 50% as compared with the earlier method of diffuser washing. Counter current vacuum washing systems are being installed in new kraft mills.

The other discharges from the pulping operations include log wash water, digester relief and blow down condensates, turpentine decanter water and floor washings. These are generally lower in volume and strength (B.O.D.) as compared with the overflow from the decker seal pit.

The chief waste from the chemical recovery system is the condensate from the evaporators. Use of barometric condensers produces an effluent low in oxygen demand but high in volume, while use of a surface condenser gives a low volume of waste water relatively high in B.O.D. Employment of long tube evaporators, utilizing up to seven effects, reduces the entrainment loss, or carry-over, responsible for high losses previously experienced in this operation. The development of better foam control and trapping devices has helped materially to minimize black liquor carry-over into the condensate.



Usually facilities are now provided along with the black liquor evaporators to remove the 'sulphate soap' and tall oil, with the liquor from the soap skimmer being conveyed on to the last stage of the multiple-effect evaporators. The soap may be sold to refiners. There is a market for tall oil. If not reclaimed, the skimmings need to be sent to the cascade evaporator and recovery furnace for concentration and burning to minimize components in the mill effluent that in sufficient concentrations may be toxic to fish and aquatic life.

Lime sludge is dewatered and calcined for reuse, or may be lagooned and utilized as agricultural lime. The remaining waste waters from the chemical recovery section of a mill are small in volume and low in strength as regards pollution.

#### OTHER PULPING PROCESSES AND EFFLUENTS

It will be understood from the foregoing discussion that the waste effluents from pulp mill operation carry materials which vary with the process used and with the efficiency of individual plant operation. In the other principal chemical pulping processes, sulfite and soda, more than half of the wood used is dissolved in the cooking liquor leaving a residue of cellulose fibers as pulp. The spent liquors contain lignin, hemicellulose, and sugars in solution and a small amount of fiber in suspensions which is lost in the washing and dewatering operations.

Sulfite waste liquor (calcium base process) is usually discharged into adjacent waterways without further treatment. After extensive investigations on a pilot-plant scale by three different companies, the first commercial installation of a new recovery process for the chemicals and organic matter normally discharged as waste was made at Longview, Washington.

In this modified sulfite process magnesium oxide is used in place of the lime which customarily has been employed as the base for the cooking liquor. The process is generally referred to as the magnesium base sulfite process. Because of the necessity to recover in excess of 95 percent of the magnesium oxide for economical operation, the waste liquor is removed as completely as possible from the pulp by counter-current vacuum washers. The washings as well as the waste liquor drained from the pulp are evaporated to about 60 percent total solids and burned in a waste liquor recovery boiler.

In addition to the recovery of the magnesium oxide, most of the sulphur and the fuel value of the organic solids, are recovered. The



waste heat boiler supplies the steam required for cooking, evaporation of the liquor, and other requirements of the pulp mill in addition to supplying as a byproduct much of the electric power needed in the plant.

An attractive feature of this process particularly in locations where fuel is scarce and its cost high, is the utilization of the fuel value of these waste liquors to supply the normal steam and power requirements of the pulp mill. This new process now fairly well proven on a commercial scale reduces the necessity for other means of disposal of the liquor. With good operation of such a pulp mill, studies indicate there would be much less effect on the waters into which any effluent of the mill would be discharged than with the calcium base sulfite process.

The same advantage from the point of view of water pollution reduction over the usual sulfite pulping method applies to the ammonia base process. The plan of operation is essentially as described above except the ammonia is lost up the stack in present mills in burning the organic material removed from the pulpwood.

The so-called semi-chemical process for pulping wood is particularly suitable for use of hardwoods. From the waste utilization point of view it is desirable when this process is utilized to operate it along with a kraft pulp mill.

Since the groundwood pulping process employs only a mechanical grinding of wood, the effluent from this process carries in solution only a very small amount of water-soluble material extracted from the wood. Also carried in suspension is a small amount of fine wood fibers which pass through the wire screens used in dewatering the pulp.

Pulp bleaching as a step toward production of high grade pulp and paper products is simply indicated on the flow diagram, Figure 7, without going into the various steps employed in a modern bleaching system. In the study of mill sites in Montana, the basis of comparison in determining the relative suitability of proposed locations as regards effluent disposal, no attempt has been made to go into a detailed account of effects of converting the pulp into paper products.

To provide some understanding of the procedures employed and waste ingredients, the following brief outline of paper manufacture is presented:



### PAPER PRODUCTION EFFLUENTS

In the paper-making process, the sheet is formed by filtering the fibers from a water suspension on a fine-mesh wire screen. In the formation of the paper sheet, the water passing through the screen (white water) carries a considerable quantity of fiber. In order to avoid large losses of fiber, this white water is recirculated through the system. In other words, instead of adding fresh water for washing and dilution of pulp stock, the white water is added for this purpose. However, it usually results that there is a surplus of white water over that needed for make-up and the unused portion, after passing through filters or settling tanks, is discharged into the mill effluent. In addition to the cellulose fibers, white water effluent from paper mills may contain some clay or other mineral fillers, alum, rosen-size, and dye used in the manufacture of various kinds of paper. The quantities of suspended solids in the effluent from both pulp and paper mills may vary considerably among individual mills. This is a result of the different products being manufactured, the process used, type of equipment available, and method of operation.

The so-called 'white water' wastes, applied to the fiber and other paper making materials in suspension, are kept at a minimum by recirculation. Save-all equipment is employed to remove the paper making solids in the white water before discharge from mills. There is usually some type of filtering or clarifying device designed to return the reclaimed material to the pulp and paper-making process. Utilizing more recent equipment, the losses of fiber can reasonably be kept below a half pound per thousand gallons of effluent.

### SUMMARY ON WASTES

The present procedure in pulp and paper mills is to reduce wastes at their source, reclaiming as much of processing chemicals and wastes as practical, returning these materials to the system for pulp and paper manufacture. An increasing number of by-products have been developed from wastes. Reduction in mill losses have brought about very substantial decreases in pollution caused by effluents.

Recycling of process waters has done much to reduce volumes of effluents. As indicated, the usual volumes per ton of kraft pulp in modern mill practice range from 20,000 to 40,000 gallons. The strengths of the wastes should definitely be kept under a population equivalent of 400 per ton. With careful operation the strengths should be substantially less than this number.



There is a trend toward monitoring of effluents, using automatic control equipment to reveal increases in strengths of wastes due to leaks, spills and other unusual or emergency conditions arising in mill operation. Diversion of wastes at these times to lagoons, or other suitable means, have been utilized to avoid "slugs" of pollution. It is very important to make provision for avoiding such difficulties in the design and construction of new mills.

Summarizing briefly kraft mill waste disposal procedures, consideration should be given to the following items:

1. Dry bark and waste wood -- should be utilized or burned, ashes to be kept out of streams.
2. Screen rejects -- reclaimed or burned.
3. Grit and dregs from lime slaker --- disposed of on dump, or utilized for fill, surfacing material, etc.
4. Tall oil and soap --- to be removed and either marketed or incinerated.
5. Fly ash -- to be disposed of other than discharged to stream.
6. Fibers in white water -- to be kept at minimum by efficient saveall system.
7. Chemicals dissolved in effluent -- loss to be kept at minimum with modern reclaiming equipment, including countercurrent vacuum filter washing of pulp. Consider waste monitoring and control equipment and lagooning for wastes.
8. Lime sludge -- recovery and reuse, or disposal for agricultural lime.
9. Sanitary sewage -- treated and disposed of in a sanitary manner.
10. Refuse -- incinerated or disposed of in such manner as to be kept out of streams.

Such considerations have entered into the estimates of effects of mill wastes on streams at sites previously described. Other factors involved are discussed in the following sections:



## FACTORS IN THE STUDY

Generally the most important effect of pulp and paper mill effluents on aquatic life is considered to be the removal of oxygen from the water into which the effluent is discharged. If the volume of water receiving the effluent is not large enough, or its oxygen content is low the oxygen depletion may result in reduction of the dissolved oxygen to a level below that necessary to sustain fish life. The dissolved oxygen tends to be gradually restored by natural aeration. A dissolved oxygen content of at least five parts per million is considered necessary for trout and salmon. Stream flow therefore becomes an important consideration.

### Stream Data:

This study did not include a detailed field survey of the streams for the collection of specific analytical data indicating the present sanitary, biological, physical, and chemical condition of the waters. Data utilized in this study were limited to those which were available from existing records of various governmental and private agencies.

Stream temperature data were obtained from the Livingston and Billings municipal water plants on the Yellowstone River and from the Montana Power Company for a location near Great Falls on the Missouri River. Stream flow data were obtained from the records of the U.S.G.S. gaging station which most accurately reflected the stream flow at each particular site. Information on the relative importance of fishery resources and extent of recreational uses of the various sectors of the streams was obtained from discussion with persons familiar with them.

Data on the types and quantity of wastes presently being discharged to the streams were obtained from reports on the Yellowstone (1) and Upper Missouri River Drainage Basins. It was necessary to estimate the present dissolved oxygen concentration and biochemical oxygen demand of the stream waters from knowledge of the characteristics of the streams, pollution known to be entering, and related information obtained from the Montana State Board of Health.

### Water Quality Objectives:

The effect of kraft pulp mill wastes on existing and possible future installations of drinking water supplies is the introduction of color, taste and odors. The probable extent of such effects was considered for each site. The effect on industrial water supplies would generally not be appreciable although the wastes may make some section of the rivers less suitable for a few industries with special process water quality requirements. Available information indicates there are no such industries presently taking water from these sections of the streams.



Kraft pulp mill wastes may add some color, odors and possibly cause some foaming in the stream below the mill waste outlets. Under certain conditions some wood fiber may be deposited on the bottom of quiescent areas of the stream, some of which may later rise to the surface. The high fiber recovery efficiency attainable in modern mills will minimize this possibility. The probable extent of such effects on the esthetic quality of the waters at each site is described.

Based on information obtained, it is assumed that all sectors of the streams under consideration except below Billings are suitable habitat for, and contain substantial cold water fish populations. Below Billings the stream is naturally suitable for other kinds of game fish. Maintenance of over-all stream conditions suitable for such fish populations is considered an essential requirement to be met at any pulp mill site selected. The dissolved oxygen (D.O.) criterion used in this analysis is that a minimum of 5 ppm of D.O. be maintained in the stream at the most critical conditions expected to occur once in ten years.

Certain constituents in kraft pulp mill wastes are toxic to fish and other aquatic organisms when present in sufficient concentration in the stream. Dimick and associates (3) have demonstrated that the effluents from three different kraft mills when diluted 1:20 did not kill silver salmon under laboratory conditions.

The data obtained in a biological study (3) of one Pacific Northwest stream consisting of investigations before and after the beginning of operation of a kraft pulp mill give some indication of the toxic effects of kraft pulp mill wastes on the suitability of a stream for salmon and steelhead trout. The pulp mill wastes were discharged in such a manner that apparently the wastes were distributed in only one-half of the width of the stream in the sector studied. Assuming that this half was effectively utilized for uniform disposal of wastes in the water, the dilutions in this situation would be in the ratio of 1 to 50. The affected area of the stream was unsatisfactory for most desirable fish food organisms and unfit as a spawning area for fish. It extended a distance of 2.2 miles below the mill outlets where the stream joined a larger river and observable biological effects disappeared.

From the above information and additional fish toxicity data reported by Van Horn, Anderson, and Katz (4), and Cole (5), the following basis was selected for evaluating such toxic effects pulp mill wastes might have on aquatic life at sites considered:

Fish will not be killed in dilutions of mill wastes to stream flow of 1 to 50 where conditions are otherwise suitable for fish. At dilution of 1 to 75 or above, there will be negligible, if any, detrimental toxic effects on fish food organisms, spawning areas, or other factors of the stream environment that may indirectly reduce existing fish populations.



Inasmuch as irrigation is a major use of the waters of both the Missouri and the Yellowstone Rivers, the effect of the pulp mill wastes on the suitability of the waters for this purpose is an important consideration. There appears to be relatively little specific information on the effects of pulp mill wastes on irrigated crops or on the soil. There are no known instances of detrimental effects of kraft pulp mill wastes on irrigated crops. With dilution of pulp mill waste by flow in the ratio of 1 to 50, the total increase of the sodium cation in the stream will be less than 2 ppm. The total increase in sulfides will be less than 0.2 ppm. The above concentrations are considerably below those found in waters considered excellent for irrigation (4). The concentration of other cations, anions, and organic materials resulting in the stream from the pulp mill wastes should not have a significant effect on the suitability of the water for irrigation. Inasmuch as at normal flows the dilution ratio will be greater than 1 to 50, it is improbable that the pulp mill wastes will have any detrimental effect on irrigated crops.

#### Methods of Analysis:

It was assumed that a hypothetical kraft pulp mill of 200 tons per day capacity would be located at one of the following sites: Livingston or Billings on the Yellowstone River, and Three Forks, Winston, or Great Falls on the Missouri River. As previously indicated, a population equivalent of 400 per ton of pulp produced was used in these estimates. This is based on the results of numerous determinations of the biochemical oxygen demand (B.O.D.) of wastes discharged in studies made of a considerable number of kraft pulp mills, obtained from records of the Wisconsin Committee on Water Pollution, and other sources. This represents operating data of plants constructed prior to World War II. Recent studies show a modern mill can be operated with significantly less waste discharge, so the use of the above value introduces a factor of safety into the calculation. A waste flow of 40,000 gallons per ton of pulp is used in this study.

The minimum stream flows which would be expected to occur within various periods of time were estimated by the probability method developed by Gumbel (7) as adapted by the Environmental Health Center, Public Health Service for predicting low flow frequency. The estimated 10 year minimum summer and winter flows for each site are shown in Table 1. These were selected as the critical flows on which other estimates are based.

The minimum or critical values of dissolved oxygen below the proposed sites were calculated using the oxygen sag curve formula developed by Streeter and Phelps as modified by Fair (8). The value of the self



purification constant selected for each site was on the conservative side of the ranges suggested by Fair for streams of similar flow characteristics. Reduced values were used for winter conditions to compensate for possible effects of ice coverage. The B.O.D. loading of the stream at each site used in the computations included the following:

1. An assumed B.O.D. of the stream above the site of 1.5 ppm ult. @ 20° C. (approximately 1.0 ppm 5 day B.O.D.).
2. The B.O.D. of the known municipal and industrial wastes presently being discharged at each site.
3. The B.O.D. of the wastes discharged by the pulp mill.
4. The increase in B.O.D. of the municipal wastes resulting from an estimated gain in population of 2,400 persons due to construction of the mill.

The B.O.D. loading of the stream at each of the sites is shown in Table 3.

Saturated conditions of dissolved oxygen in the stream above each site was assumed in keeping with information furnished. The dissolved oxygen values are also shown in Table 3.

#### Stream Flow Studies:

The Yellowstone River in the vicinity of Livingston is a very fast flowing stream with many rapids and very turbulent flow. It is a relatively cold stream. Its maximum temperature in 1951 was 62° F. during parts of July and August. The flow is markedly less during the winter period. The minimum daily flow of each year of record has occurred during the months of December to March, inclusive. Minimum daily summer flows occur in August and September, and average about 2-1/2 times minimum winter flows. Based on a 15 year period of record the estimated 10 year minimum daily flow in the winter is 585 second feet as compared to 1,460 second feet during the warm weather periods.

In the vicinity of Billings and below, the flow is slower and much less turbulent than at Livingston, but is still fairly fast. Maximum yearly temperatures of the stream recorded by the Billings Water Plant for the years 1946 to 1950 ranged from 68°F. in 1950 to 72° F. in 1946. As at Livingston, minimum daily flows occur during the cold weather months of December to March, inclusive, and minimum summer flows occur



during August and September. Minimum daily winter flows are significantly higher than at Livingston. The estimated 10 year minimum daily winter flow based on a 16 year period of record is 960 second feet, and for the summer period is 1,530 second feet.

The Missouri River, below Three Forks, is a medium fast flowing stream with some sections of turbulent flow and has good reaeration characteristics. However, much of the B.O.D. of the mill effluent discharged at Three Forks will be exerted after it enters the Canyon Ferry Reservoir where reaeration will proceed at a lower rate. Temperatures of the stream at this locality will probably be modified somewhat when the reservoir is completed. It is probable that the maximum temperature of the stream will be somewhat less than the 75° F. recorded at Great Falls and assumed for this location. Estimates of stream flow at Three Forks are based on the data of the U.S.G.S. stream gaging station at Toston, located about 25 miles below Three Forks. The minimum daily flow for each year generally occurs during cold weather months, but there is less difference between minimum summer and winter flows on this section of the Missouri than is true of Upper Yellowstone flows. Minimum daily winter flows of each year of record, have occurred in December, January, or March. Minimum summer flows occurred in July, August, and September. The estimated 10 years minimum daily winter flow based on a 13 year period of record is 1,250 second feet, and minimum summer flow is 1,400 second feet.

With the completion of the Canyon Ferry Reservoir, its backwaters will extend to the vicinity of Winston. Estimates of minimum daily stream flows entering the reservoir are based on Toston gaging station records, and are similar to those reported for the Three Forks stream flow.

There are several 'Run of the River' power plants on the Upper Missouri in the vicinity of Great Falls (See Figures 5 and 6). There is good water movement through the reservoirs, as they have relatively limited storage capacity. Estimates of stream flow at Great Falls are based on records of the U.S.G.S. gaging station at Fort Benton located 42 stream miles below Great Falls. The minimum daily flow in recent years has occurred during winter months, but in a few years summer flows have been the lowest. Minimum daily flows during the cold weather period have occurred in the months of November, December, January and February. Minimum daily summer flows have occurred during the months of July, August and September. Although mean annual flows of the Missouri in the vicinity of Great Falls are higher than mean annual



flows below Three Forks, the estimated 10 year minimum daily flows are equivalent. Based on a 30 year period of record, the estimated 10 year minimum daily winter flow at Great Falls is 1,250 second feet, and 1,400 second feet for the summer period. Montana Power Company temperature records of the stream near Great Falls for the six year period of August, 1946 to July, 1951 show a maximum temperature of 75°F.

### SUITABILITY OF SITES

#### Livingston:

The turbulent flow, high summer flow, and relatively low temperature characteristics of the Yellowstone near Livingston give it a greater capacity to assimilate oxygen consuming wastes and maintain adequate dissolved oxygen concentration than any of the other proposed sites. With the discharge of the wastes from a 200 ton kraft pulp mill, the calculated D.O. concentrations at the 10 year minimum summer flow is 7.9 ppm. At 10 year minimum winter flows it is 10.9 ppm.

At minimum stream flows the concentration in the stream of any components of the mill wastes toxic to fish would be greater at Livingston than at any of the other sites studied. The estimated 10 year minimum winter flow of 585 second feet is less than one-half the minimum flows at Three Forks, Winston, or Great Falls on the upper Missouri and significantly less than at Billings. The dilution ratio of mill wastes to a stream flow of 585 second feet is 1 to 47.4. Dilution ratios of less than 1 to 75 are expected to recur at an average of once every 1.8 years. At these low dilutions it is expected that the toxic effects of the wastes will reduce the quantity of desirable fish food organisms present and render some existing fish spawning areas unusable in a limited sector of the stream below mill waste outlets. This would tend to reduce the total fish population in the vicinity. Noticeable odor, color, and foam in the stream from the mill wastes should be limited to a very short sector of the stream below the mill.

The nearest public water works presently obtaining water from the Yellowstone is located at Columbus, which is about 120 stream miles below Livingston. It is improbable that a pulp mill at Livingston would result in any material amounts of taste and odor producing substances in the Yellowstone River at Columbus. There will be little, if any, additional load on the present treatment processes, and the quality of the treated water should not be affected. It is expected that any drinking water supplies taken in the future from the stream up to 50 miles below a mill at Livingston might experience taste and odor problems because of the mill wastes, particularly during winter periods.



The pulp mill is not expected to have any material effect on the suitability of the Yellowstone River water for irrigation purposes.

Analysis of the available information and data indicates that the only serious pollutional problem to be resolved in utilizing this site for a 200 ton kraft mill relates to toxicity of the wastes to aquatic life and their probable effects on the fish populations in the vicinity of the mill. This does not necessarily preclude the possibility of establishing a mill at this site, but does indicate that one at this location will need to reduce the toxicity of its waste below that necessary at the other proposed sites to adequately protect the aquatic life in the stream.

#### Billings:

The population equivalent of organic industrial and municipal wastes presently being discharged to the Yellowstone River at Billings for which an estimate is available is 420,000 (5). In addition, there are several industries discharging significant amounts of organic wastes for which a quantity estimate is not available. There are also some inorganic industrial wastes being discharged to the Missouri. Four hundred thousand of the estimated 420,000 population equivalent is from the Great Western Sugar Company beet sugar refinery. The operation and waste discharge from such refineries generally occur during the months of October, November and December. Minimum daily winter flows in some years will occur when wastes are being discharged by the sugar refinery. Critical summer stream temperature and flow conditions will not normally coincide with waste discharge from the refinery, but in some years the critical dissolved oxygen conditions may occur during the early part of the refinery season when stream temperatures are still fairly high. It was assumed in the computations of critical D.O. conditions that the sugar refinery waste discharge would coincide with critical summer as well as winter conditions. The error introduced by this assumption tends to compensate for the appreciable but unknown quantity of organic wastes being discharged to the stream which was not included in the calculations. The calculated D.O. concentration of the stream at 10 year minimum winter flows shown on Table 8, is 9.0 ppm and 4.3 ppm for summer flows. It is to be noted that 4.3 ppm of dissolved oxygen is less than the concentration of 5 ppm stated before to be the minimum for a suitable habitat for fish.

The estimated 10 year minimum winter flow of 960 second feet shown in Table 3 is significantly greater than the 10 year minimum flows at Livingston, but is lower than the minimum flows at any of the other sites considered. The dilution ratio of mill wastes to stream flow at 960



second feet flow is 1 to 77.7 which is essentially equal to the dilution ratio, (1 to 75), believed necessary to prevent any harmful toxic effects of the mill wastes on the aquatic life in the stream.

There will probably not be any noticeable effects from the effluent from a pulp mill at Billings on the water supply of Forsyth, Montana, which is 115 miles downstream. Appreciable taste and odor effects of the wastes on any drinking water supplies taken from the river in the future would probably be limited to about 50 miles downstream from Billings.

There will be some color, odor, and foaming from the mill wastes in a short sector of the stream below the mill outlets. This should not be of such content as to be objectionable. The quality of the stream waters for irrigation purposes will not be affected.

It appears from the information available that with the quantity of organic wastes now being discharged into the river at Billings the addition of a pulp mill effluent will lower the dissolved oxygen concentration below that which is desirable for fish. A major reduction in the wastes presently being discharged is essential before Billings can be considered a suitable pulp mill site.

#### Three Forks:

The establishment of a 200 ton kraft pulp mill at Three Forks will reduce the dissolved oxygen concentration in the stream to an estimated minimum of 5.6 ppm about once in 10 years. This minimum dissolved oxygen concentration will occur in the Canyon Ferry Reservoir. Probably less than one-half of the oxygen demand of the wastes will be satisfied before reaching the reservoir. For all practical purposes it should be completely stabilized in the reservoir.

The dilution ratio of mill wastes to the stream flow with the estimated 10 year minimum winter flow, is 1 to 101. At this dilution there should not be any appreciable effect on the aquatic life following complete mixing of the wastes in the river. Immediately below the mill waste outlets, where there is appreciably incomplete mixing of the wastes with the stream water, there may be some reduction of fish food organisms and impairment of fish spawning areas but this sector will be so limited that it should not affect the desirable fish population of the stream in the vicinity.

Any impairment of the suitability of the Missouri River as a source for drinking water supplies due to the mill wastes would be limited



principally to the sector above the Canyon Ferry Dam. The mill wastes would not make it unsatisfactory for this use, but it is possible that some additional treatment for taste and odor removal may be necessary. At present there are no public drinking water supplies obtaining water from this portion of the stream.

The esthetic quality of the stream a short distance below the mill waste outlet may be impaired somewhat due to some foaming, odors, and color from the wastes. There is also the possibility that some wood fibers lost during production might accumulate on the bottom in the upper part of the reservoir. It is improbable there will be any appreciable effect on the quality of water for irrigation purposes.

It appears from the analysis of the available information and data that a 200 ton kraft pulp mill could be established at Three Forks without creating material pollution of the stream. There will probably be little effect on the fish populations in the stream and very limited effect on the suitability of the stream water for other uses.

#### Winston:

It is assumed that the proposed kraft pulp mill will be located so as to discharge wastes into the Upper Missouri River above the backwaters of the Canyon Ferry Reservoir where the total flow of the stream is continually available for dilution of the mill wastes.

In the computation of the minimum or critical conditions of dissolved oxygen that may occur in the reservoir, it is assumed that the extent of dilution of the wastes which will take place within 3 days of their discharge is limited to mixing with the water flowing in the river. This does not take into consideration the fact that within this period of time there will likely be mixing of the wastes with some additional quantity of water in the reservoir which will increase the D.O. concentration. This should tend to compensate for any Benthic demand effects of possible wood fiber deposits on a limited bottom area in the upper part of the reservoir, which were not considered in the calculation. The estimated minimum D.O. which will occur in a limited part of the reservoir about once in 10 years is 5.6 ppm. Dissolved oxygen concentrations throughout the major portion of the reservoir will be considerably higher. For all practical purposes the B.O.D. of the mill wastes should be satisfied in the reservoir.

The dilution ratio of mill wastes to stream flow at the estimated 10 year minimum winter flow is 1 to 101, which is appreciably greater than the dilution considered necessary to protect the fish and other aquatic life of the stream due to any toxic effects of the mill wastes.



As at Three Forks, there will be some reduction of desirable fish food organisms in a limited area below the mill waste outlets, before there is complete mixing of the wastes with the stream water, but this is expected to be so limited that it should not reduce the fish population of the stream.

Inasmuch as adequate D.O. concentrations will exist in all parts of the stream and reservoir and the toxic effects on fish food organisms will be limited to a relatively small part of the stream and reservoir, the over-all effect of the mill effluent on the total fish population should not be appreciable.

The taste and odor producing compounds in the pulp mill wastes will reduce the suitability of the Canyon Ferry Reservoir water as a source for public drinking water supplies to the extent that color, taste and odor removal treatment may be needed to produce acceptable water. It is not expected that such condition will exist below the reservoir.

Color, odor, and possibly some foaming caused by the mill wastes may be observed in the immediate vicinity of the mill waste outlets.

Available information indicates that the mill wastes will not affect the suitability of the water for irrigation.

The pollutional effects of a pulp mill located at Three Forks would be cumulative to a considerable extent with those of another mill located at Winston. It appears that there might be deleterious effects on the aquatic life in the Canyon Ferry Reservoir if 200 ton capacity kraft pulp mills are constructed at both sites.

Analysis of the available information and data indicates that a 200 ton kraft pulp mill near Winston, discharging wastes into the Missouri River above slack water, will not result in material depreciation of the water quality for other uses.

Some consideration was given to estimating resultant effects on the stream or reservoir from discharge of the pulp mill wastes into the slack water. Although some impression exists that discharge of the wastes into the slack water may result in appreciable local nuisance effects, with possible detrimental effects on fish population in the reservoir, it is impractical to estimate such effects without having accurate information of the reservoir currents at the specific site to be considered. This should be obtained through a field study of the flow characteristics, or currents, to be made after completion of the reservoir. Construction of a mill discharging wastes into the slack water should not be considered until such a study is made and it indicates that dilution of the



wastes will be sufficiently rapid to prevent any objectionable effects on other water uses.

### Great Falls:

The establishment of a 200 ton kraft pulp mill at Great Falls will reduce the dissolved oxygen concentration of the stream to an estimated minimum of 5.9 ppm about once in ten years. This is based on the assumption that future minimum daily flows at the mill site will be comparable to the flows recorded at Fort Benton during the period from 1919 to 1948. Limited information obtained relative to the planned regulation of releases from the Canyon Ferry Reservoir indicates that the minimum flows in the vicinity of Great Falls will be somewhat higher in the future. This would tend to reduce the estimated effects of the existing wastes and a pulp mill effluent discharged to the stream at this location.

The dilution ratio of mill wastes to stream flow at the 10 year minimum winter flow is 1 to 101. The only expected toxic effects are some reduction of desirable fish food organisms and suitable fish spawning areas in a limited portion of the stream below the mill waste outlets where mixing of wastes and stream water is not complete. This should have little, if any, effect on the fish populations in the vicinity.

It is unlikely that the mill wastes will appreciably increase the color, taste, and odor of the treated Fort Benton water, but there is a possibility that such effect may be noticeable during occasional periods of low winter flow. Some additional treatment of the water may be necessary. Noticeable color, odor, and foam in the stream will be limited to a short distance below the waste outlets. It is unlikely that the wastes will affect the suitability of the water for irrigation purposes.

Analysis of the available information and data indicate that a 200 ton kraft pulp mill at Great Falls will not have appreciable detrimental effect on the stream quality for various uses considered. From a stream pollution standpoint this site appears to be one of the more suitable sites.



### SUMMATION

The foregoing findings are the results of field observations and study which included (1) assembly and analysis of hydrologic, estimated waste discharge and available water quality data; and (2) correlation of collected information in terms of appropriate water quality objectives based on water use. The study necessitated the evaluation of future dissolved oxygen conditions in the Yellowstone and Upper Missouri Rivers, forecast under various drought probabilities with kraft pulp mills of 200 ton daily capacity located at the various sites along these streams; and consideration of the anticipated effects of the effluents on other stream characteristics related to present and certain possible future uses.

The importance of maintaining a high degree of cleanliness in the relatively unpolluted portions of the streams, and of providing for suitable utilization, treatment and disposal of existing and future pollutional wastes is recognized. Montana has a valuable asset in its cold, clear waters from snow capped mountain areas. These waters are already utilized for the benefit and enjoyment of both the citizens and visitors to the State. Accordingly, the essential problem is to conserve to the fullest extent possible the values of these waters for all purposes.

The State has renewable timber resources that it has had an increasing market for up to the present time, including pulpwood. This pulpwood, produced for the most part in the South Central Montana, is now being exported to mills in the Midwest. There is a desire to utilize a substantial part of the potential pulpwood production of forest areas as a raw material for pulp manufacturing in the State.

The pulpwood available, including a considerable amount of deadwood in addition to the expected annual crop of green wood, is sufficient to very adequately support operations at several mills located East of the Continental Divide, this being the only area considered in this report. The kind of wood is quite suitable for pulping by the sulphate (kraft) process. Accordingly, this type of process is currently being given primary consideration.

The sulphate, or kraft, process, considered in detail, consists essentially of digestion of wood chips under steam heat and pressure with a sodium sulfide cooking liquor, or solution, to separate the cellulose fibers from the other organic material. The spent liquor remaining in the pulp after an initial draining is removed in modern mills with vacuum washers. It then is evaporated and burned for the recovery of chemicals and the fuel value of the dissolved organic material. The waste effluent from the mill carries small quantities of chemicals, dissolved organic solids and suspended fibers in the wash water.



Large quantities of water are needed in producing pulp and paper. In the manufacture of a ton of kraft pulp the requirement in newer mills will range from 20,000 to 40,000 gallons. The waste produced will probably range in oxygen demand per ton of pulp from a population equivalent of 200 to 400, with carefully operated modern mills having effluents near the lower figure. In the studies made in Montana the higher of these values as regards both volume and strength was used, introducing a factor of safety in the computations made in forecasting stream conditions.

It should be pointed out also that an appreciable further allowance is made in appraising stream conditions with effluents to be anticipated from 200 ton kraft pulp mills by using the low river flows (computed from U.S.G.S. data), under both summer and winter conditions, that occur with a frequency of once in 10 years. These more critical conditions for dilution of mill effluents will be approached for only limited periods during each year.

Process and equipment improvement have resulted in a definite trend downwards in the volume and strength of unbleached kraft pulp and paper mill effluents. The strength of the wastes on an oxygen demand basis has been decreased as much as 75% by such improvements, with attendant reduction in chemical requirements. Monitoring equipment is providing of value in avoiding occasional increases in sewer losses. The work on waste reduction is nearing an irreducible minimum, however, and further reductions necessitate consideration of treatment and disposal methods.

Such measures for treatment and disposal as have been employed in recent years with kraft mill wastes, have been directed toward reduction in waste components toxic to fish life as well as to reduction in oxygen demand. An example of a toxic waste stripping treatment method installed in kraft mills is the so-called Bergstrom tower process. It removes a large portion of toxic sulphides and mercaptans from the composite mixture of blow steam condensate, evaporator condensate, and digester relief condensate following separation of the turpentine which is usually marketed or burned.

Lagooning has been utilized with beneficial results in reducing the strength of kraft mill wastes, and in equalizing the flow and variations to be expected in strength of mill wastes. The use of lagoons of suitable capacity for effluents, therefore, gives flexibility in handling of wastes to avoid objectionable conditions during periods of low stream flow and highest water temperatures. Special studies in recent years to increase the efficiency of lagoons have been conducted by the industry through their Council on Stream Improvement, and much information is available on performance of this method of treatment and disposal of kraft mill effluents.



Biological methods of treatment, similar to those currently used in sewage treatment practice, with the addition of nutrients to support the organisms involved, are currently being studied in pilot plants. Results with the activated sludge process at one mill have been quite impressive to date, giving a high degree of reduction of the oxygen demand. Further work will need to be carried out, however, before the process can be recommended for mill-scale application.

In conclusion, the observations and studies indicate the more suitable sites of those suggested for the development of a kraft pulp industry in Montana, viewed from the point of view of probable effect of effluents ~~on~~ on the Yellowstone and Upper Missouri Rivers. This preliminary survey should be followed by detailed evaluation of conditions when definite information is available covering individual mill projects. Suitable operation and treatment provisions can be determined for each project to enable attainment of a high degree of stream cleanliness consistent with water uses.

Respectfully submitted by:

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H. A. Anderson, Public Health Engineer

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L. F. Warlick, Sanitary Engineer Director  
Chief, Technical Services Branch



TABLE 1. MINIMUM DAILY FLOWS

Site	Years of Record	Minimum Daily Flow of Record Sec-Ft.	Minimum Flow 5 yr. Return Period Sec-Ft.	Minimum Flow 10 yr. Return Period Sec-Ft.
Livingston				
Winter	15	590	700	585
Summer	15	1,330	1,670	1,460
Billings				
Winter	16	960	980	960
Summer	16	1,530	1,770	1,530
Three Forks*				
Winter	13	1,180	1,550	1,250
Summer	14	1,370	1,720	1,400
Winston*				
Winter	13	1,180	1,550	1,250
Summer	14	1,370	1,720	1,400
Great Falls*				
Winter	29	830	1,780	1,250
Summer	29	627	1,950	1,400

\* Toston Gaging Station Records

\*\* Fort Benton Gaging Station Records

TABLE 2. DILUTION RATIO OF MILL WASTES TO STREAM FLOW

	Dilution Ratio at 10 yr. Minimum Daily Flow
Livingston	
Winter	1 to 47.4
Summer	1 to 118
Billings	
Winter	1 to 77.7
Summer	1 to 121
Three Forks	
Winter	1 to 101
Summer	1 to 113
Winston	
Winter	1 to 101
Summer	1 to 113
Great Falls	
Winter	1 to 101
Summer	1 to 113



# SUMMARY OF STREAM DATA AT PROPOSED KRAFT PULP MILL SITES

Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
Total B.O.D. of Stream Including Mill Wastes (1) Ppm. Ult. at 20°C	Total B.O.D. of Stream Ppm. Ult. at Stream Temp.	Critical D.O. of Stream Ppm.	Assumed Value of Self Purification Constant (f <sub>20</sub> )	Critical Time to Days
8.4	5.1	10.9	1.0	7.9
4.4	4.1	7.9	4.0	2.2
25.7	15.4	9.0	1.0	7.3
16.7	17.5	4.3	3.0	2.2
4.6	2.8	11.5	0.54	10.9
4.3	4.6	5.6	1.2	3.5
4.6	2.8	11.6	0.44	12.1
4.3	4.6	5.6	1.0	3.9
6.0	3.6	11.9	1.0	7.9
5.6	6.0	5.9	2.0	2.7

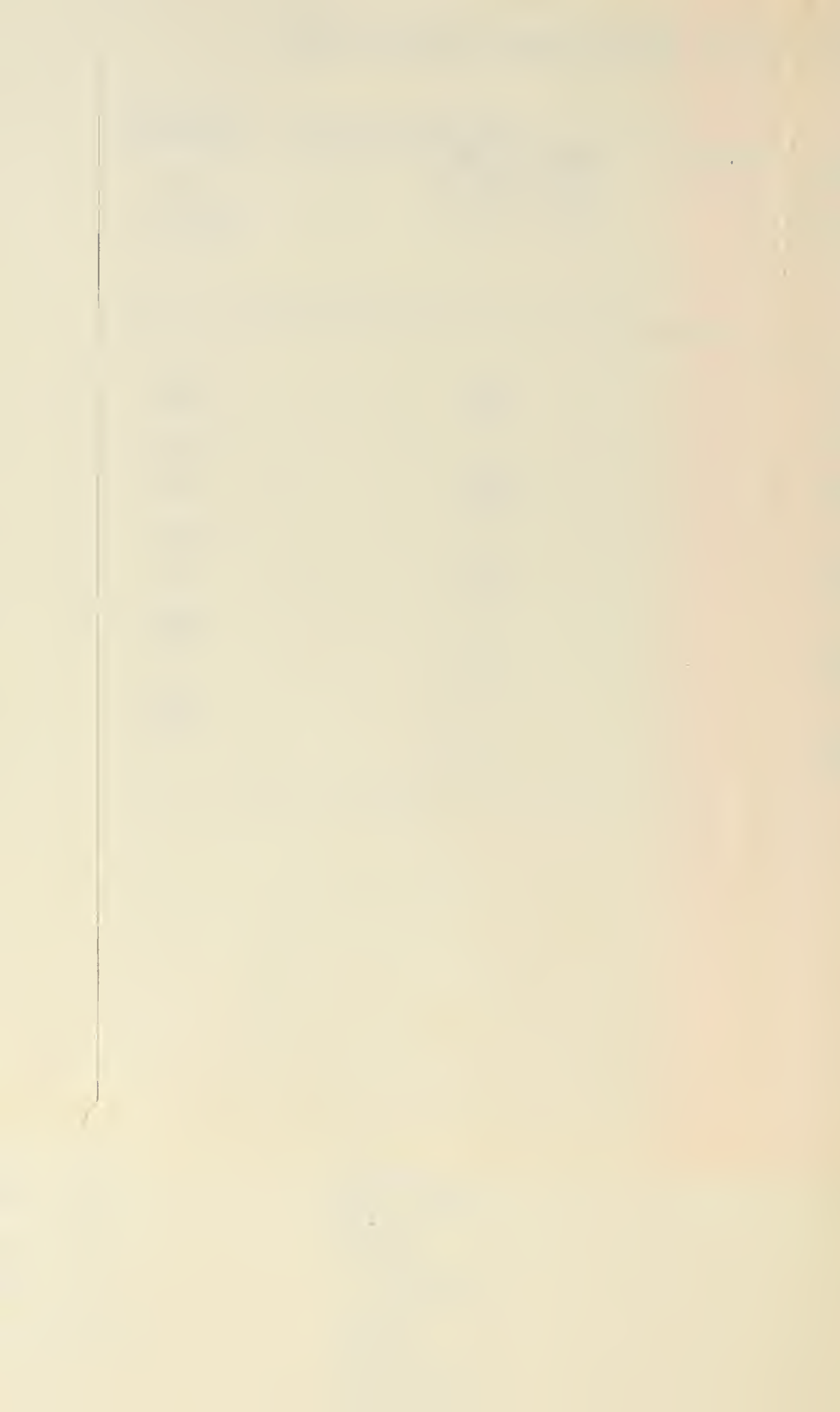


TABLE 3.

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
	10 year Minimum Daily Flow Sec-ft.	Temp. of Water of	D.O. at Sat. Ppm.	B.O.D. of Stream Added by Present Municipal and Industrial Wastes Ppm. Ult. @ 20°C	B.O.D. of Stream Added by Mill Wastes Ppm. Ult. @ 20°C
Livingston					
Winter	585	32	12.3	0.6	6.3
Summer	1,460	62	8.4	0.3	2.5
Billings					
Winter	960	32	13.0	20.3	3.9
Summer	1,530	72	7.9	12.7	2.4
Three Forks					
Winter	1,250	32	12.6	0.04	3.0
Summer	1,400	75	7.3	0.03	2.7
Winston					
Winter	1,250	32	12.7	0.0	3.0
Summer	1,400	75	7.4	0.0	2.7
Great Falls					
Winter	1,250	32	12.9	1.5	3.0
Summer	1,400	75	7.5	1.3	2.7

1. Includes assumed 1.5 ppm B.O.D. of stream above all waste discharges of community and increase in municipal wastes from estimated 2400 population increase due to mill.



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## Valletta River Boat Excursions, Porters

The railroad downwinds from Succ Creek and 5 miles south of Livingston.

Dr. J. B. Jones, M.D.

2022-2023

[illegible]

Minimum: 550 second-foot January 22, 1940 (Bachmator from 100)

Remarks: Run a good except for periods of ice effect which are poor. Many diversions above station.

2005-2006



# STREAM FLOW DATA

Yellowstone River at Billings.

Location: 1 mile northeast of Billings.

Average Discharge: 17 years 6,445 second-feet.

Extremes Maximum: 64,800 second-feet June 27, 1944

Minimum: 430 second-feet December 12, 1932

Remarks: Records good except those for periods of ice effect or no gage height record which are fair. Many diversions above station.

Discharge Data in second-feet.

Year	Minimum Daily Discharge				Maximum Daily Discharge	Mean Annual Discharge	Minimum Monthly Mean Discharge	
	Nov. Discharge	- April Month	May Discharge	- Sept. Month			Discharge	Month
1948	1,650	Feb.	2,600	Sept.	54,100	8,274	2,644	Feb.
1947	1,600	Feb.	3,850	"	41,400	7,863	2,274	"
1946	1,000	Dec.	2,570	Aug.	30,100	6,316	2,692	Dec.
1945	1,200	Dec.	3,940	Sept.	43,800	7,045	2,291	Feb.
1944	2,000	Mar.	3,250	Aug.	48,800	7,068	2,414	"
1943	1,500	Jan.	4,200	Sept.	57,800	10,220	2,588	Jan.
1942	1,700	Jan.	2,930	Sept.	45,800	7,643	2,686	Feb.
1941	1,000	Jan.	3,040	Aug.	21,800	4,899	1,874	Jan.
1940	1,190	Feb.	1,530	"	26,700	4,686	1,363	"
1939	1,000	"	2,180	Sept.	28,400	5,474	1,832	Feb.
1938	1,220	Feb.	2,670	"	41,700	6,832	1,911	Dec.
1937	1,090	Dec.	1,560	"	33,400	5,071	1,852	Jan.
1936	960	Apr.	2,040	Sept.	32,800	5,487	2,102	Feb.
1935	970	Jan.	2,000	"	36,900	5,361	2,043	Mar.
1932	1,380	Feb.	2,970	"	36,900	3,220	1,560	Feb.
1931	1,980	Dec.	1,900	Aug.	25,700	4,390	2,300	Dec.



# STREAM FLOW DATA

Missouri River at Toston, Montana

Location: Two miles S. E. of Toston. Estimated to be somewhat over 30 river miles below Three Forks. 1910-16 data obtained at site 2½ miles further downstream.

Drainage Area:

Average Discharge:

Extremes Maximum: 33,000 second-feet June 6, 1948

Minimum: 362 second-feet (regulated) Est. Feb. 10, 1914

Remarks: Records generally good. Some regulation by reservoirs on tributaries. Broadwater canals with capacity of 350 second-feet have diverted water for irrigation from point 3 miles above station since 1940.

Discharge Data in Second-Feet

Year	Minimum Daily Discharge				Maximum Daily Discharge	Mean Annual Discharge	Minimum Monthly Mean Discharge	
	Nov. Discharge	April Month	May Discharge	Sept. Month			Discharge	Month
1943	2,620	Jan.	3,100	Aug.	33,000	6,936	3,489	Sept.
1947	2,100	Jan.	2,660	Aug.	21,400	6,145	2,975	Aug.
1948	2,500	Dec.	1,980	Aug.	11,400	4,405	2,462	"
1945	2,050	Dec.	2,120	July	11,800	4,073	2,486	"
1944	2,460	Mar.	2,460	Aug.	18,500	4,761	2,931	"
1943	1,710	Jan.	2,620	Sept.	25,500	6,313	3,102	Jan.
1942	1,650	Jan.	1,500	Aug.	26,100	5,562	1,816	Aug.
1941			1,320	July				
1916	1,640	Dec.	3,630	Sept.			3,890	Dec.
1915	1,730	Dec.	5,660	Sept.	13,100	5,600	2,750	Jan.
1914	2,480	Jan.	1,730	Aug.	19,900	5,770	2,240	Aug.
1913	1,510	Jan.	3,110	Sept.	29,800	6,990	2,430	Jan.
1912	2,020	Mar.	3,380	July			3,060	Mar.
1911	1,180	Jan.	1,820	Aug.	24,900	5,060	2,460	Aug.



# STREAM FLOW DATA

Missouri River at Fort Benton, Montana

Location: At highway bridge at Fort Benton. Fort Benton is 31 wood miles below Great Falls. River mileage estimated to be somewhat greater.

Drainage Area: 24,600 Sq. Miles

Average Discharge: 8,181 second-feet 67 years

Extreme Maximum: 140,000 second-feet June 7, 1948

Minimum: 320 second-feet July 5, 1936

Remarks: Records good except for periods of ice effect or no gage height which are fair. Many diversions from tributaries above station. Some regulation by reservoirs. Considerable diurnal fluctuation at medium and low flow caused by power plants above station.

Discharge Data in Second-Feet

Year	Minimum Daily Discharge				Maximum Daily Discharge	Mean Annual Discharge	Minimum Monthly	
	Nov. Discharge	April	May	Sept. Month			Mean Discharge	Month
		Month	Discharge					
1943	3,440	Jan.	4,620	Sept.	51,300	10,720	5,386	Jan.
1947	1,800	Nov.	3,330	"	31,100	8,852	4,079	Aug.
1943	3,200	Dec.	2,790	"	16,100	5,935	3,698	Aug.
1945	2,800	Dec.	2,800	Aug.	22,400	6,005	3,524	Aug.
1944	3,600	Feb.	3,700	Sept.	29,800	6,836	4,322	Sept.
1943	3,000	Jan.	3,960	"	37,100	9,480	4,291	Oct.
1942	3,200	Jan.	2,790	"	31,400	7,978	3,417	Aug.
1943	2,200	Jan.	2,180	"	13,000	4,091	3,038	Aug.
1940	1,600	Dec.	2,270	"	11,700	4,320	2,920	Sept.
1939	2,500	Dec.	2,340	"	14,500	5,461	3,255	Sept.
1933	1,960	Jan.	2,540	"	26,600	6,012	2,762	Jan.
1937	1,420	Jan.	1,950	"	6,110	3,621	2,492	Feb.
1936	1,240	Feb.	627	July	17,600	4,559	2,872	Feb.
1935	830	Dec.	2,010	Sept.	16,700	4,307	2,921	Nov.
1934	2,520	Feb.	1,190	Aug.	16,200	4,952	1,576	Aug.
1933			1,690	Aug.	24,400	5,890	3,000	Dec.
1932	895	Jan.	1,680	Sept.	22,400	5,350	2,380	Jan.



Fort Benton - Cont'd

Year	Minimum Daily Discharge				Maximum Daily Discharge	Mean Annual Discharge	Minimum Monthly Mean Discharge		
	Nov. Discharge	April Month		May Discharge			Discharge	Month	
		Month	Month						
1931	2,170	Feb.		1,900	July	9,090	4,150	2,650	Aug.
1930	2,610	Dec.		2,700	Aug.	16,900	5,500	3,210	Aug.
1929	3,760	Jan.		3,680	Aug.	20,800	6,880	5,030	Sept.
1928	3,590	Dec.		4,100	Sept.	33,400	9,910	5,100	Jan.
1927	2,710	Dec.		4,810	Aug.	52,900	10,800	4,640	Dec.
1926	3,040	Jan.		3,190	Aug.	19,900	7,300	4,590	Aug.
1925	2,100	Dec.		2,860	Aug.	29,500	7,790	3,980	Oct.
1924	2,740	Feb.		2,950	July	23,800	6,460	3,510	Aug.
1923	2,940	Dec.		3,400	Sept.	23,700	7,660	3,980	Oct.
1922	2,840	Nov.		3,450	Sept.	34,100	8,310	3,970	Feb.
1921	2,760	Dec.		3,050	"	31,500	7,880	3,300	Aug.
1920	2,040	Dec.		3,220	"	30,700	7,520	2,440	Oct.
1919	2,920	Feb.		1,420	Aug.	13,900	5,070	2,070	Sept.

